Dating of Rocks from the Bungonia District, New South Wales

P. F. CARR, B. G. JONES and A. J. WRIGHT

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The lower part of the Bungonia Limestone contains fossils of Ludlovian (late Silurian) age but no age-diagnostic fauna has been identified from the upper part of the formation or from the overlying Tangerang volcanics. The K-Ar radiometric age determination reported in this study from the Tangerang volcanics (399 m.y.) appears to be too low, suggesting radiogenic argon loss. K-Ar radiometric data for rocks from the southern part of the Marulan Batholith yield a mean age of 398 m.y. (early Devonian). Since the Tangerang volcanics overlie the Bungonia Limestone and are intruded by the Marulan Batholith they are probably early Devonian. It is suggested that the Tangerang volcanics are a correlative of the Bindook Porphyry which is also intruded by the Marulan Batholith. The southern part at least of the Bindook Porphyry is therefore probably also early Devonian. Extrusion of the Tangerang volcanics, deformation of the Ordovician to early Devonian strata and intrusion of the Marulan Batholith are considered to have been related to the Bowning Orogeny.

P. F. Carr, B. G. Jones and A. J. Wright, Department of Geology, University of Wollongong, P.O. Box 1144, Wollongong, Australia 2500; *manuscript received 11 July 1979, accepted after revision 24 October 1979.*

INTRODUCTION

Bungonia lies approximately 150 km southwest of Sydney near the western margin of the southern Sydney Basin. Rocks in the Bungonia district (Fig. 1) range in age from Ordovician to Devonian with a few erosional remnants of younger sedimentary and volcanic rocks. The Ordovician to Devonian strata were deposited in the eastern part of the Lachlan Fold Belt and have been described or mentioned by many earlier authors (*e.g.* Woolnough, 1909; Naylor, 1935, 1936, 1939, 1950; Packham, 1969; Moore, 1976).

The aim of the present study was to determine the age of the Bungonia Limestone, Tangerang volcanics and Marulan Batholith. This investigation provides new data derived from K-Ar dating and fossils. All radiometric age determinations presented in this study were carried out by S. Lafferty and D. C. Green using facilities at the Department of Geology and Mineralogy, University of Queensland and techniques outlined by Sutherland *et al.* (1973). The K-Ar ages have been calculated using the preferred decay constants of Steiger and Jäger (1977).

PRE-PERMIAN REGIONAL SETTING

The Ordovician sequence consists of multiply-deformed siltstones, cherts and quartzites yielding late Ordovician graptolites at a few localities (Naylor, 1935, 1938). Early Silurian shales and siltstones overlie the Ordovician rocks in a small area 6 km west of Bungonia (Naylor, 1935). East of Bungonia the Ordovician strata are unconformably overlain by, or faulted against, late Silurian limestones and shales (Woolnough, 1909) which contain corals, brachiopods, bryozoans, crinoids, nautiloids, trilobites and graptolites (Moore, 1976; Carr *et al.*, at press). Regionally the late Ordovician and late Silurian strata appear to occupy two asymmetrical meridional synclines reaching as far north as the Wombeyan Caves (Naylor, 1935,

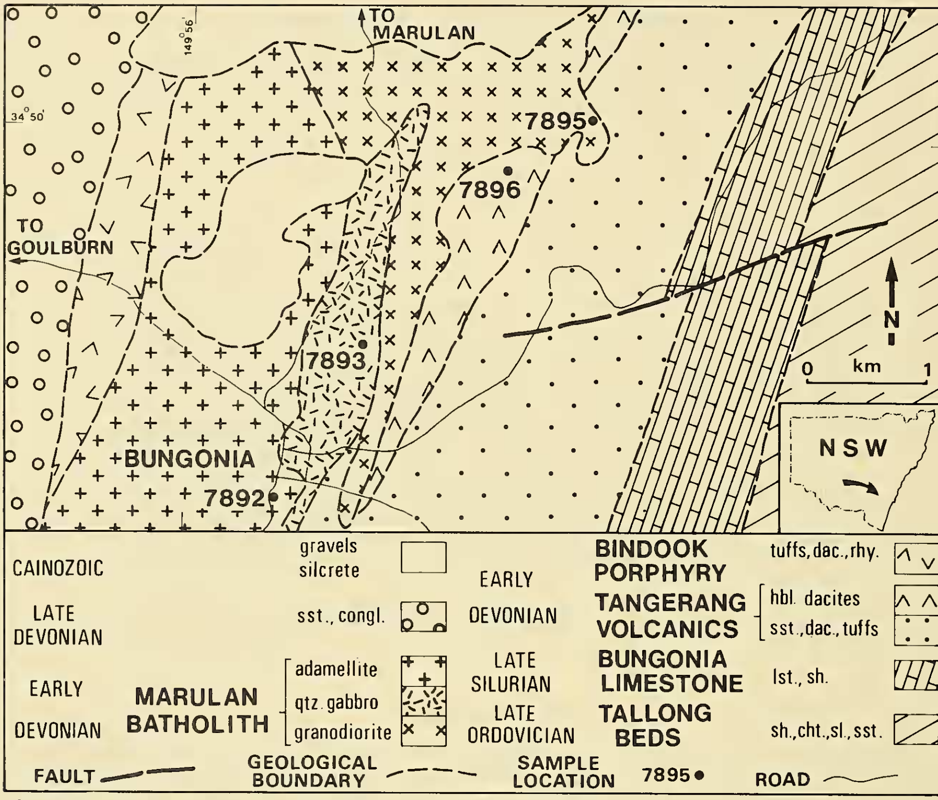

Fig. 1. Locality map and geology of the Bungonia area.

1950) and extending southwards to Windellama (Garretty, 1937) and Bendithera Caves (Packham, 1969). In the South Marulan area Wass and Gould (1969) have shown that the late Silurian limestones and shales are conformably overlain by the Tangerang volcanics which comprise dacites and tuffaceous sedimentary rocks. This sequence is known to extend southwards to Bungonia (Kantsler, 1973; Moore, 1976; Carr *et al.*, at press). Wass and Gould (1969) suggested that the Tangerang volcanics are late Silurian to early Devonian in age. Dacitic and tuffaceous outcrops of the Bindook Porphyry (McElroy and Relph, 1961; Packham, 1969) extend north from Marulan for approximately 70 km to Yerranderie and show many characteristics in common with the Tangerang volcanics. The age of the Bindook Porphyry is known on stratigraphic grounds to be between latest Silurian (Packham, 1969, p.134) and late Devonian (Powell and Edgecombe, 1978).

All the Ordovician and Silurian units have been intruded by the Marulan Batholith (Woolnough, 1909; Osborne, 1949) which is a composite body extending almost continuously from near Bungonia to about 8 km south of Bullio. The batholith contains a variety of rock types including granite, granodiorite and quartz-hypersthene porphyry (Osborne, 1949; Joplin *et al.*, 1952; Osborne and Lovering, 1953).

Age Determinations

Bungonia Limestone. Previous estimates of the age of the Bungonia Limestone, based largely on corals, were middle to late Silurian (Woolnough, 1909; Wass and Gould, 1969). More recently Moore (1976) suggested a late Silurian age based in particular on a graptolite fauna including *Bohemograptus bohemicus tenuis* (locality 1, Appendix I), and shelly fossils including encrinurid and phacopid trilobites and the brachiopod *Plectodonta bipartita* (locality 2, Appendix I). These fossils occur in the lower part of the Bungonia Limestone. Rickards *et al.* (1977, fig. 45), indicated that *B. b. tenuis* is late Ludlovian, ranging from the *leintwardinensis* zone to the *kozlowskii* zone. Conodont data (Pickett, 1972; Dean-Jones, *pers. comm.,* 1978) are in agreement with this late Silurian age. No age-diagnostic fossils have yet been identified from the upper part of the formation. Therefore the lower part of the Bungonia Limestone is late Ludlovian, and the uppermost beds should prove to be either latest Silurian or early Devonian.

Marulan Batholith. The Marulan Batholith intrudes the Bungonia Limestone near South Marulan (Osborne, 1931) and is unconformably overlain by late Devonian sedimentary rocks to the west of Bungonia (Naylor, 1939). Hence on stratigraphic grounds the batholith is younger than late Silurian but older than late Devonian. Evernden and Richards (1962) obtained a Carboniferous age (313 m.y.; recalculated using new constants) for biotite from the batholith and were aware of the anomaly as were Vallance (p.198, *in* Packham, 1969) and O'Reilly (1972). In the present study a biotite separate from each of three different phases of the batholith was dated (Table 1 and Fig. 1). The three age determinations are consistent with the sequence of emplacement demonstrated by field studies (*i.e.* granodiorite (oldest), quartz gabbro, adamellite), although when the errors (Table 1) are considered, there is no significant age difference between the three dates. The mean age for the emplacement of the southern part of the Marulan Batholith is 398 m.y. (early Devonian) which is consistent with its age on the basis of the local stratigraphy.

The age obtained for the southern part of the Marulan Batholith by Evernden and Richards (1962) is inconsistent with the stratigraphy and the ages obtained in the present study. Radiogenic argon was probably lost by the sample.

Tangerang volcanics. The only previous published reference to the age of the Tangerang volcanics is that of Wass and Gould (1969) who suggested a late Silurian to early Devonian age for the toscanites, tuffs and tuffaceous sandstones which appear to overlie the Bungonia Limestone conformably. In the Bungonia area the Tangerang volcanics consist of plane-bedded, cross-bedded or massive lithic to sublithic sandstones (tuffaceous in part) and thick lensoidal dacite and hornblende dacite units. The dacites in the upper part of the Tangerang volcanics contain hornblende phenocrysts which are absent from the lower dacites.

TABLE I

K-Ar data for igneous rocks from the Bungonia area

Sample Number	Rock type	Material dated	Latitude south	Longitude east	K_2O % (av.)	$^{40}Ar^*$ (10^{-5}cc/gm)	% $^{40}Ar^*$	Age (m.y.)
7892	adamellite	biotite	34°51.7'	149°56.5'	6.63	9.413	90.5	393 ± 7
7893	quartz gabbro	biotite	34°50.9'	149°56.9'	7.23	10.313	74.8	395 ± 8
7895	granodiorite	biotite	34°49.9'	149°58.2'	7.05	10.374	94.8	406 ± 7
7896	hornblende dacite	hornblende	34°50.1'	149°57.7'	1.12	1.616	93.4	399 ± 7

$\lambda_\beta = 4.962 \times 10^{-10}\ yr^{-1}$; $\lambda_e + \lambda'_e = 0.581 \times 10^{-10}\ yr^{-1}$; $^{40}K = 0.01167$ atom %

Errors are taken at the 95% confidence level.

Sample numbers refer to the University of Wollongong rock collection.

Fossils found within this unit (localities 3 and 4, Appendix I) indicate that it was at least partly deposited under marine conditions. However, the fossils, which are poorly preserved bryozoans, crinoid ossicles and rare corals, do not provide a refined age for the unit.

A K-Ar age determination was carried out on a hornblende separate from sample 7896 of the hornblende dacite (Table 1, Appendix II). The age of 399 m.y. is very close to the mean age obtained for the emplacement of the Marulan Batholith *which intrudes the volcanics*. Thus the 399 m.y. date for the Tangerang volcanics is probably too young to represent the age of extrusion of the hornblende dacite, and may result from loss of radiogenic Ar by the hornblende.

On the basis of the K-Ar ages for the Marulan Batholith, the Tangerang volcanics were extruded more than 398 m.y. ago. The maximum age of the formation is provided by the Bungonia Limestone, so the Tangerang volcanics must have been extruded during the early Devonian (or possibly the latest Silurian).

Woolnough (1909), Naylor (1935) and Osborne and Lovering (1953) considered the silicic volcanic rocks in the Marulan area (Tangerang volcanics of Wass and Gould, 1969) to be shallow intrusions and to be intimately associated in time, and possibly comagmatic, with the rocks of the Marulan Batholith. O'Reilly (1972), however, concluded that the Marulan Batholith and the silicic volcanics were 'discrete entities'. The new data show that the volcanics and the rocks of the batholith are indeed closely associated in space and time and a genetic relationship between the two, as suggested by earlier workers, is possible.

Bindook Porphyry. The Bindook Porphyry is a meridionally-trending belt of dacites, rhyolites, crystal and lithic tuffs and hypersthene porphyrites (McElroy and Relph, 1961). At Yerranderie only the upper dacite flows in the Bindook Porphyry contain biotite and hornblende (Joplin *et al.,* 1952). Jones *et al.* (1977) noted the abundance of ash-flow tuffs in the Yerranderie area and suggested that the dacites and tuffs are remnants of an early to middle Devonian volcano. Powell and Edgecombe (1978) concluded that late Devonian strata unconformably overlie the Bindook Porphyry near Yerranderie. O'Reilly (1972) described part of the western margin of the Bindook Porphyry (invalidly named 'Brayton Volcanics' as Brayton limestone [Naylor, 1950] has priority) as a series of extrusive toscanites and dacites and associated tuffs. She assigned (O'Reilly, 1972) a late Silurian to early Devonian age to the unit based on its apparent conformity with the Silurian sequence in the Brayton area, and the contact metamorphic effects where the Bindook Porphyry is intruded by part of the Marulan Batholith (Lockyersleigh adamellite).

It is suggested that the Tangerang volcanics are a correlative of the Bindook Porphyry based on the following:

(1) although the units are separated by intrusions of the Marulan Batholith, the Tangerang volcanics form a possible southerly extension of the Bindook Porphyry;
(2) both occupy a similar stratigraphic position in that at least part of each unit conformably overlies late Silurian limestones (Wass and Gould, 1969; O'Reilly, 1972); and
(3) both are similar, consisting of hypersthene-bearing acid volcanics, with hornblende dacites largely restricted to the upper parts of the sequences.

The suggested correlation of the Bindook Porphyry and Tangerang volcanics implies an early Devonian age (possibly extending to latest Silurian) for at least the southern part of the Bindook Porphyry.

Implications

The new stratigraphic and radiometric data contribute to our understanding of the Bungonia district. The unconformity below the late Devonian strata indicates that there was post-early Devonian folding. In terms of the orogenies recognized in this part of the Lachlan Fold Belt, this phase of folding could represent either the Bowning Orogeny or the Tabberabberan Orogeny. However, the K-Ar ages (mean 398 m.y.) indicate that the southern part of the massive Marulan Batholith was emplaced during the early Devonian. Thus the Bungonia area records the Bowning Orogeny which was responsible for movements occurring at the end of the Silurian and throughout the early Devonian (Packham, 1969). Associated with the orogeny in this area was the extrusion of the Tangerang volcanics, the subsequent folding of the Ordovician to early Devonian strata, and the intrusion of the batholith.

Acid volcanics of early Devonian age — which occur at Yarrangobilly, Canberra, south of Cowra, northwest of Forbes and west of Molong (Packham, 1969) — are possible correlatives of the Bindook Porphyry and Tangerang volcanics, as are the volcanics in the Bowning Group at Bowning (Link and Druce, 1972). In addition to the Marulan Batholith, other large granite and granodiorite batholiths including the Kosciusko Granite, the Murrumbidgee Batholith and the Gunning-Wyangala Batholith were emplaced during the Bowning Orogeny (Packham, 1969).

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Appendix I

FOSSIL LOCALITIES

Locality 1. Bungonia Limestone. Ludlovian (late Silurian). Grid reference 715365, Kooringaroo 1:25,000 Series Topographic Map. Fauna includes: trilobites, ? *Encrinurus* and cf. *Phacops crosslei;* brachiopods, *Plectodonta bipartita,* cf. *Visbyella.* Identifications by A. J. Wright.

Locality 2. Bungonia Limestone. Ludlovian (late Silurian). Grid reference 729396, Bungonia 1:25,000 Series Topographic Map. Fauna includes *Bohemograptus bohemicus tenuis.* Identification by G. H. Packham.

Locality 3. Tangerang volcanics. Possibly latest Silurian in part, probably early Devonian. Grid reference 005017, Caoura 1:31,680 Series Topographic Map. Fauna includes indeterminate crinoid ossicles, corals and bryozoans. Identifications by P. F. Carr and B. G. Jones.

Locality 4. Tangerang volcanics. Possibly latest Silurian in part, probably early Devonian. Grid reference 732427, Bungonia 1:25,000 Series Topographic Map. Fauna includes indeterminate corals and crinoid ossicles. Identifications by P. F. Carr and B. G. Jones.

Appendix II

Brief descriptions of samples dated by K-Ar method. Sample localities are specified by grid references from the Bungonia 1:25,000 Series Topographic Map.

7892 Medium- to coarse-grained adamellite consisting of K-feldspar, plagioclase, quartz, biotite, hornblende, apatite, zircon, sphene and iron-titanium oxides. Alteration has produced chlorite, sericite, epidote and prehnite. The biotite is slightly chloritized and contains minor prehnite. G.R. 689385.

7893 Medium- to coarse-grained quartz gabbro consisting of plagioclase, augite, biotite, hypersthene, hornblende, iron-titanium oxides, interstitial quartz and minor apatite and K-feldspar. Alteration has produced sericite, carbonate, fibrous amphibole and pyrite. The biotite is slightly chloritized. G.R. 697397.

7895 Medium- to coarse-grained granodiorite consisting of plagioclase, K-feldspar, quartz, biotite, hornblende, iron-titanium oxides, diopside, hypersthene, apatite and zircon. Alteration has produced chlorite, fibrous amphibole, prehnite, epidote and kaolinite. The biotite is slightly chloritized. G.R. 716416.

7896 Porphyritic hornblende dacite with phenocrysts of quartz, hornblende, plagioclase and hypersthene in a very fine-grained groundmass of quartz, plagioclase, K-feldspar, hornblende, biotite, hypersthene and iron-titanium oxides. Alteration has produced chlorite, sericite and kaolinite. The hornblende is slightly chloritized. G.R. 709412.